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A Review on Strengthening of RCC Columns with Composite Wrapping Systems and Alternative Materials

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ABSTRACT

The increasing urbanization and rising building loads have placed significant demands on the load-bearing capacity of columns, which are critical structural elements in buildings. The load-carrying capacity of these columns is often limited due to higher loads from additional floors, necessitating the use of strengthening techniques. Various methods, such as jacketing, FRP wrapping, and bonding with steel plates, have been employed globally to enhance column performance. Furthermore, the depletion of natural aggregates has led to the exploration of alternative materials in the concrete industry. These alternatives, including tire rubber, glass waste, plastic, and recycled aggregates, help in reducing environmental impact while promoting sustainability. Secondary cementitious materials such as fly ash, GGBS, and silica fume also play a vital role in producing self-compacting concrete (SCC), which improves both mechanical and durability properties.

This research focuses on exploring the impact of composite wrapping techniques on the structural behavior of reinforced self-compacting concrete columns made with alternative fine aggregates and cement partially replaced by fly ash. The aim is to assess the effectiveness of composite wrapping using glass and jute fibers in improving the performance of columns and compare these results with conventional concrete columns of similar grade. The study integrates experimental and analytical investigations to evaluate the load-carrying capacity, deformation, and failure loads of these composite-wrapped columns, with results compared using finite element analysis (ANSYS).

1. INTRODUCTION

Over a period, structural elements are subjected to deterioration due to many reasons, such as environmental effects. Many times, these structural elements required retrofitting in view of improving or regaining their properties and making them functionally safe. Confining the structural elements via wrapping or jacketing, using high- performance concrete or self-compacting concrete (SCC) and utilizing materials other than conventional constituent materials of concrete have gained researchers attention in past years.

Applications of SCC and fiber reinforced polymer wrapping are promising to ease the problems of segregation and compaction and are found to be constructive ways to improve structural performance of the members.

The columns in any framed structure are key load-transferring members supporting the superstructure above ground; hence their collapse can be viewed as the failure of the entire construction. To counteract these issues, several approaches have been established to improve the structural behavior by improving properties such as ductility, load bearing capacity and other severe characteristics. However, major care should be taken during construction to avoid segregation, honeycomb formation or exposure of reinforcements, improper compaction and etc. Otherwise, improper homogeneity will negatively affect structural behaviour and also poses a negative effect on durability of the concrete.

Hence, it is required to work on improving the isotropy and homogeneity of the concrete by incorporating marginal materials besides conventional concrete materials to produce structurally sound members.

1.1 Use of alternative materials as building material

The growing global focus on sustainability, environmental impact and resource efficiency has led to increased interest in search of alternative materials for construction acvtivity. These materials are often sought as replacements or supplements to conventional building materials like concrete, steel and brick, which have significant environmental footprints due to their production processes, resource consumption and waste generation. The exploration of alternative materials not only eliminates environmental concerns but

also opens up opportunities for innovative and cost-effective construction solutions.

Alternative materials, often derived from natural, recycled or bio-based sources, offer several potential advantages over traditional materials. They can reduce the carbon footprint of construction projects, minimize waste and contribute to the circular economy by reusing materials or utilizing renewable resources. Moreover, alternative materials can provide unique performance characteristics, such as greater thermal insulation, reduced weight or enhanced durability, making them suitable for a wide range of applications in modern construction.

Depletion of river sand, has led to environmental imbalances and depletion of raw materials. To address this, alternative fine aggregates (AFA) such as crushed rock sand (CRS), industrial by-products (IBP), and recycled fine aggregates (RFA) offer sustainable solutions. These materials improve concrete's economic, environmental, and social aspects by reducing waste and reliance on natural resources [1],[2], [3].

Crushed Recycled Concrete Aggregates (CRCA) as a substitute for natural sand (NS) in concrete, The experimental results on compressive strength, split tensile strength, and flexural strength at different curing ages showed 100% CRCA replacement yielded improved compressive strength compared to 50% and 0% CRCA and suggested that controlled particle size gradation of CRCA will be helpful in sustainable construction [4].

incorporating natural granite (NG), silica slag (SS), marble powder (MP), and basalt (GB) significantly improved the compressive strength of concrete. Concrete with these mineral wastes also showed higher ultrasound speeds and compressive strengths compared to the control. The sulphate resistance and abrasion resistance of these concretes was at greater extent to that of the controlled ones [5].

1.2 Use of sustainable materials in the development of SCC

For instance, incorporating fly ash or slag as partial substitutes for cement helps to decrease the energy-intensive production of Portland cement, a significant source of greenhouse gas emissions. Furthermore, utilizing recycled aggregates reduces the need for natural resources and minimizes waste. By incorporating these materials, SCC can maintain or even enhance its performance while promoting environmentally responsible construction practices.

1.2.1 Self-Compacting Concrete

Self-compacting concrete (SCC) also referred as super-workable concrete is a highly flow-able or self-levelling concrete which spreads without any external force. SCC
has very high segregation resistance and hence can be placed easily [6]. It is formerly called as high-performance concrete (HPC), however concept of HPC transformed then its name is changed to SCC. It is used in highly congested reinforcement where vibration is difficult. Japanese scientist Hajime Okamura invented SCC during 1980's when there was non-uniformity and incomplete compaction in conventional concrete was a problem in hand, which resulted in poor performance.

SCC is highly flow-able adequate to penetrate through highly reinforced section. hardened properties are influenced by the characteristics of aggregate [7].

Application of SCC has steadily risen in past years owing to the use of SCC over conventional concrete in very complicated reinforcement section and placement in narrow section. Currently many countries using SCC in major projects and is succeeding in overcoming contemporary problems. The prerequisite for self- compacting concrete is:

1.2.1.1 Filling ability - Capability of concrete to fill complex reinforcement under its own weight

1.2.1.2 Passing ability - Capability of concrete to pass through congested reinforcement and bond to it under its own weight without segregation or blocking

1.2.1.3 Segregation resistance – ability of SCC to resist the segregation and maintain its homogeneity until its placed.

To achieve the above properties and to avoid obstruction in highly reinforced section, the SCC should be designed properly. Maximum size of aggregate, amount of CA are limited to achieve the best result [8].

However, when there is need of high workability, the concrete tends to segregate result in unfavourable condition. Viscosity modifying agents (VMA) are used to reduce the segregation and increase the stability of the air-void system. Early SCC depended on more cement content and superplasticizer in order to avoid segregation. But larger content of cementitious paste also leads to shrinkage [9]. However, use of high cement content is restricted as per codal provisions. In order to reduce high cement content, pozzolanic materials were added as cement replacement. Many such available filler materials are fly ash, rice husk ash, GGBS and etc., [10], [11], [12]. One such filler material widely in use is fly ash, which is an unused product from coal industry and poses a problem in its disposal. Thus, incorporation of fly ash in civil engineering works leads to green initiative. Also, the incorporation of fly ash improves the properties of concrete as it reduces the shrinkage, heat of hydration, creep, permeability and also improves the surface finish [13], [14]. The fly ash helps in long term strength development and durability due to its pozzolanic.

1.3 Advantages of SCC

A. Overall cost of construction is considerably reduce.
B. SCC can be easily used in congested reinforcement places.
C. There is no need of any vibrator, as it is self-compacting.
D. No bleeding and segregation.
E. Good surface finish and aesthetical appearance.
F. Thinner sections can be easily casted through SCC.
G. The working procedure is totally safe.
H. Use of alternative green materials the concrete can be made environment friendly.
I. The durability of concrete can be increased.
J. Noise level is low due to no vibration.

1.4 Disadvantages of SCC

A. The casting rate will be reduced, due prerequisite of water-tight joints.
B. Require intense curing, otherwise plastic shrinkage cracking appears due low water-cement ratio.
C. Skilled labours are essential to produce SCC.
D. The cost required for material is higher compared to conventional concrete however overall construction cost will be lower.

1.5 Applications of SCC

Now a days SCC has become key technique in all constructions including precast construction instead of regular concrete. While designing SCC all the parameters concerning to mix should be addressed. Practical application of SCC is extended from large infrastructure building to architectural buildings also. Some of the practical applications of SCC in India are Delhi metro project, atomic power projects at Kaiga and Tarapur.

1.6 Column strengthening

Columns are one of the most critical structural elements in buildings and bridges. They transfer the loads from the superstructure to the foundation, mainly resisting compressive forces. Over time, columns may deteriorate due to several factors including environmental degradation, overloading, poor construction practices, design errors, seismic activity and aging. These issues can compromise the load-carrying capacity, stability and safety of a structure. Strengthening techniques aim to restore or enhance the performance of these columns to extend the structure's lifespan and improve safety.

In this chapter, various techniques for strengthening columns will be explored, with a focus on modern practices and their practical applications.

Importance of Strengthening Columns

A. Safety: Failure of a column can lead to partial or total collapse of a structure.
B. Longevity: Strengthening helps to extend the life of aging or damaged structures.
C. Seismic Retrofitting: In areas prone to seismic activity, retrofitting columns ensures they meet updated earthquake-resistant codes.
D. Load Upgrade: Strengthening allows the structure to carry additional loads due to

changes in building use or height.

A. Environmental Damage: Columns exposed to corrosion, freeze-thaw cycles or chemical attacks need strengthening to maintain their structural integrity.

Common Reasons for Strengthening

A. Overloading due to changes in building function or design.
B. Seismic requirements in regions with higher seismic risk.
C. Corrosion or degradation of steel reinforcement due to environmental exposure.
D. Construction or design flaws discovered after erection.
E. Aging of materials causing reduced load-carrying capacity over time.

2. LITERATURE REVIEW

In a Literature, a mix containing 15% silica fume, 5% metakaolin, 20% limestone powder and 34% quartz powder resulted in improved splitting tensile strength and compressive strengths of 29% and 40% respectively[14] . In another study, the suggested dosage of expanded clay aggregates should not exceed 50% to produce self-compactable lightweight geopolymer concrete [15]. According to another literature, it is beneficial to use C&D waste to produce SCC, which can satisfy the required properties [14].

3. Literature based on lime-activated recycled aggregate concrete and GGBFS in high volumes, it was established that adding GGBFS enhanced the properties of concrete with regards to durability[36]. Usage of higher volumes of class C fly ash and lesser water to fly ash resulted in higher impact on workability [16]. A study is carried out on fiber glass waste and fly ash, which demonstrates an improvement in compressive strength by 32% compared with reference concrete and as a consequence of fly ash filling effect. Whereas in another study, it was observed that, when titanium dioxide was replaced in place of fly ash by 3%, it resulted in enhanced mechanical properties. Egg shell replacement as a fine aggregate by 10% resulted in a rise in compressive strength by 29.62%. The recycled waste aggregate from ceramic insulators was noticed to improve properties produced satisfied the structural concrete requirements. The optimal dosage of 40% of fly ash was noted when used alone and in combination with GGBS, it was noticed that intrusion of 30% is needed to obtain improvement in strength . Usage of pumice powder by 25% illustrated an improvement in performance in contrast to normal mixes, whereas the addition of fly ash showed later age strength development.

4. In a study, the best performance of concrete was obtained by using 50% fine dune sand and 35% GGBFS compared to control samples in terms of drying shrinkage[17]. the workability was absolute and also exhibited that after 0.5% of dosage, compressive strength

attains maximum value, whereas tensile strength shows a positive trend even after 0.5% up to 1%. But the workability showed positive trend as the alkaline to fly ash ratio increased, but had a negative effect on hardened properties. In another study on alkali-activated fly ash, higher content GGBS increased the ca/si ratio, resulting in lesser porosity. Also, by reducing the w/p ratio from 0.27 to 0.22 compressive strength showed a positive effect but a negative impact on tensile property.

5. In a literature based on silica as cement replacement in pervious concrete, 10% replacement of each as cementitious material showed notable improvement in durability and strength factors, the compressive strengths [18]. 20% and 2.5% of fly ash and nano- silica by weight were found to show positive effects due to combined action . In a study on SCC containing slag and fly ash, the combined action of both shown improved mechanical properties and also accountable shrinkage and thermal properties compared to when fly ash is used alone as a cement replacement.

6. In a study, replacement of cement and natural aggregate by fly ash and slag sand up to 50% was carried out and it demonstrated a beneficial impact on the durable properties of the concrete, whereas the strength attainment at the earlier ages was pretty low in comparison with control mix. A study related to incorporation of waste slag, the optimum dosages of different slags were noted to be 10–30% for steel furnace slag, 10– 50% for GGBFS, 20–50% for electric arc furnace slag and 10–60% for cupola slag. In a study on flue gas desulfurization gypsum, carbide slag and fly ash based dry-mix mortar, the obtained results indicate the potential to replace part of the cement . In a study of replacement of conventional materials in concrete by metakaolin and other industrial wastes to produce ultra-high-performance concrete, it was observed that 15% of metakaolin resulted in higher hardened properties comparatively with other variations of industrial wastes, it also improved the resistance of concrete towards chloride attack.

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